Renewable and Sustainable Energy Reviews 16 (2012) 1146–1156

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Regional sustainable water and energy development projects: A case of Southeastern Anatolia Project (GAP) in Turkey

A. Akpınar[a,b,*], K. Kaygusuz[c]

[a] *Department of Civil Engineering, Gümüşhane University, 29000 Gümüşhane, Turkey*
[b] *Department of Civil Engineering, Karadeniz Technical University, 61080 Trabzon, Turkey*
[c] *Department of Chemistry, Karadeniz Technical University, 61080 Trabzon, Turkey*

ARTICLE INFO

Article history:
Received 11 February 2011
Accepted 9 November 2011
Available online 8 December 2011

Keywords:
Southeastern Anatolia Project (GAP)
Hydroelectric
Water resources
Turkey

ABSTRACT

Southeastern Anatolia Project (GAP) region in Turkey is rich in water for irrigation and hydroelectric power. The Euphrates and Tigris Rivers represent over 28% of the nation's water supply by rivers, and the economically irrigable areas in the region make up 20% of those for the entry country. Turkey has a total gross hydropower potential of 433 GWh/yr, but only 125 GWh/yr of the total hydroelectric potential of Turkey can be economically used. By the construction of new hydropower plants, 36% of the economically usable potential of the country would be tapped. The GAP region has a 22% share of the country's total hydroelectric potential, with plans for 22 dams and 19 hydroelectric power plants. Once completed, 27 billion kWh of electricity will be generated annually.

Contents

1. Introduction

Water resources development around the world has taken many different forms and directions since the dawn of civilization. Humans have long sought ways of capturing, storing, cleaning, and redirecting freshwater resources in efforts to reduce their vulnerability to irregular river flows and unpredictable rainfall. Early agricultural civilizations formed in regions where rainfall and runoff could be easily and reliably tapped. The first irrigation canals permitted farmers to grow crops in drier and drier regions and permitted longer growing seasons. The growth of cities required advances in the sciences of civil engineering and hydrology as water supplies had to be brought from increasingly distant sources. On the other hand, our modern industrial societies routinely and dramatically modify the hydrologic cycle through unprecedented construction of massive engineering projects for flood control, water supply, hydropower, and irrigation [1–4].

* Corresponding author at: Department of Civil Engineering, Gümüşhane University, 29000 Gümüşhane, Turkey. Tel.: +90 456 233 7425x1127.
E-mail addresses: aakpinar@ktu.edu.tr, aakpinar@gumushane.edu.tr (A. Akpınar).

1364-0321/$ – see front matter
doi:10.1016/j.rser.2011.11.015

The growth of modern "conventional" irrigation since 1900 has been characterized by large water projects that harnessed rivers through the construction of diversion structures and canal systems. Since 1950, the spread of such technology accelerated through state-sponsored large-scale irrigation and an emphasis on large dams for water storage. Irrigated areas increased from 40 million hectares in 1990 to 100 million hectares by 1950 and to 271 million by 1998. Dams support 30–40% of this area, with the remainder supplied from direct river abstraction, groundwater and traditional water harvesting. Since the 1970s, the predominant focus has been on providing irrigation to support the green revolution package of hybrid seeds, chemical fertilizers and pesticides. Conditions for higher growth were created in such areas through subsidized infrastructure, agricultural inputs and electricity for pumping [2].

The planet may be largely covered with water, but over 1000 million people were estimated to be without safe drinking water in 1998 and almost 3000 million were without adequate sanitation in developing countries. This situation is not surprisingly, almost half of the world population still suffered from diseases associated with insufficient water at the beginning of the 1990s. In many cases, water resources development frequently requires large investments and longtime horizons which cannot always be easily afforded by poorer countries with scarce financial resources. In addition, high rates of population growth will continue to put severe pressure on the ability of many developing countries to provide water supply and sanitation to their unserved population [2].

Turkey has dynamic economic development and rapid population growth. It also has macro-economic, and especially monetary, instability. The net effect of these factors is that Turkey's energy demand has grown rapidly almost every year and is expected to continue growing, but the investment necessary to cover the growing demand has not been forthcoming at the desired pace. On the other hand, meeting energy demand is of high importance in Turkey. But exploiting the country's large energy efficiency potential is also vital. Air pollution is a significant problem and, as the government's projections show, carbon emissions could rise sharply if current trends continue [5–7].

The GAP will play an important role in the development of Turkey's energy and agriculture sector in the near future. For this reason, it is suitable to examine the general structure of this project and its effects. The GAP project is one of the largest power generating, irrigation, and development projects of its kind in the world, covering 3 million hectare of agricultural land. This is over 10% of the cultivable land in Turkey; the land to be irrigated is more than half of the presently irrigated area in Turkey. The GAP project on the Euphrates and Tigris Rivers encompasses 20 dams and 17 hydroelectric plants. Once completed, 27 billion kWh of electricity will be generated annually, which is 45% of the total economically exploitable hydroelectric potential [8]. In this paper, general structure of the project, the natural resources and the hydro-electrical energy generation potential of the GAP is aimed to be evaluated as well as investigating the physical characteristics of the water source systems of the region in relation to planning-application problems [8–19].

2. Sustainable development

The concept of sustainable development is not new. The general philosophy behind this concept was expounded centuries ago [2]. With the growing concerns over economic decline, population growth, the depletion of natural resources and imbalances in the apparent results of development processes, etc., attempts have been made to interpret these as consequences of the dominant discourse of development. The development process should be able to adapt to changing circumstances, to maintain or to "sustain" through flexibility [3]. Its negative impact over time and space captured the imagination of development practitioners and analysts. On the development scene, the term "sustainable development" thus became a popular catchphrase. Where a part of society is not able to meet the basic needs of life, the desirability of reviewing the whole process of development assumes paramount significance. The search for sustainable development emerged from these concepts and reflects less a consensus about what should be than a rejection [3,6,11].

Sustainability is a rather new concept in international development literature. Here, each country is expected to determine its sustainable development criteria by paying due consideration to its specific circumstances. To conduct relevant assessments in this field, the GAP Administration held a seminar in March 1995 in cooperation with the United Nations Development Program (UNDP). This seminar was attended by all sectors related to the process of development in the GAP region and set the following targets in the context of sustainability based upon the objectives and projections of the Master Plan [7–10]:

- Enhancing investments so as to ensure the maximum possible improvement of economic conditions in the region.
- Bringing education and health services up to national standards.
- Creation of new fields and opportunities for employment.
- Improving the quality of urban life and upgrading urban infrastructure so as to bring about healthier urban environments.
- Completing rural infrastructure so as to allow for optimal development of irrigation services.
- Improving intra and interregional accessibility.
- Responding to infrastructure needs of existing and future industries.
- Giving priority to maintaining the quality of water, land and air and protecting eco-systems linked to these resources.
- Promoting people's participation in decision-making and project implementation.

The basic components of sustainable development in the GAP region were identified as social sustainability, agricultural sustainability, economic viability, physical and spatial sustainability and environmental sustainability. Environmental and cultural sustainability depend upon the sustainability of natural resources and the conservation of environmental and cultural heritage. Economic viability is closely associated with the implementation of efficient and effective projects, employment opportunities, economic development and involvement of the private sector. Finally, social sustainability rests on the adoption of the principles of participation, equality, fairness and development of human resources [15–17].

3. Water and development

Today, around 3800 km^3 of fresh water is withdrawn annually from the world's lakes, rivers and aquifers. This is twice the volume extracted 50 years ago. A growing population and a rising level of economic activity both increase human demand for water and water-related services. Development, technological change, income distribution and life-styles all affect the level of water demand [2].

World population has passed 6 billion. Although the annual increase probably peaked at about 87 million around 1990, the high proportion of young people in most developing countries means that global population will continue to increase significantly well into this century. On the other hand, recent projections suggest a peak of between 7.3 billion and 10.7 billion around 2050 before

total population begins to stabilize or fall. Predictions cannot be precise, because other dimensions of development such as access to health, education, income, birth control and other services influence the pace of population growth [2].

Despite the massive investment in water resource management and particularly in dams, billions of children, women and men in rural areas lack access to the most basic water and sanitation services. Although problems of access are worst in rural areas, rapid urbanization is also increasing the demand for water-related services. In 1998, 43% of the world's population lived in urban areas. If current trends persist, that figure could reach 60% by the year 2030 and over 70% by 2050. Most of this growth will take place in developing countries where an estimated 25–50% of urban inhabitants live in impoverished slums and squatter settlements. Lack of access to water in both rural and urban areas is not just a question of supply. It is partly due to inequitable access to existing supplies [2,3].

Urbanization implies an increasing concentration on water and energy demand in mega-cities such as Istanbul and Ankara in Turkey, a switch to different lifestyles and consumption patterns, and a loss of productive agricultural land through urban expansion. It is a widely held view that lack of attention to development in rural areas is felling unsustainable forms of urban growth, shifting poverty from rural to urban areas, and contributing to rapidly growing demand for additional services [13].

4. Regional planning and administration

Regional planning is a complex process that involves policy making, collecting information, gathering problems together and resolving them, while taking economic and socio-political considerations into account. It involves the establishment of organizations and appropriate processes for planning including the formulation, implementation, evaluation and modification of plans. Regional planning is the joint responsibility of many interacting organizations and individual agents, including political and operational organizations and other groups comprising experts from various disciplines. In this sense regional planning is a complex process involving many steps which some of them are: (1) planning system is an inter-organizational system involving policy-making, management, operations, review and evaluation and in this sense; it is usually rather complex; (2) a successful plan requires the participation and support of politicians, civil servants, private sector organizations, the community and its citizens, each of which plays a distinct role; and (3) government plays an important and vital role in undertaking basic planning functions such as policy-making, preparation, execution, monitoring and evaluation [7–10].

Since each region in Turkey has different possibilities, characteristics and problems, it is indispensable to have a new planning approach in which sectoral preferences and spatial analysis are handled together. In the Ninth Plan period, studies for regional development will be benefited from in order to minimize inter-regional development disparities, to increase the level of welfare of the population living in underdeveloped regions and to stabilize the structure of migration of people. The successful preparation of the regional plans in line with the needs of the region and their implementation is possible only with the active participation of all of organizations located at the region and effected by the regional plan [4]. Within this framework, public sector has a vital and leading role to play in the preparation of regional plans. The plan is going to be prepared under the leadership of the public sector and a substantial part of the investments which are foreseen by the regional plan is going to be undertaken by the public organizations. For the successful implementation of the plan the active participation of the private sector has to be insured and the public sector has to play an important role in promoting the participation of private sector organizations [4].

5. General structure of the GAP project

The GAP integrated project initially commenced in 1936 with the hydrological surveys conducted on the Euphrates River and Keban Strait and developed towards 1960. Efforts were intensified in preparation of the feasibility of the Lower Euphrates presently consisting of 12 subprojects with the addition of the Euphrates and Tigris projects in 1970. At the present time, the Southeastern Anatolia Project (GAP) has continued to be implemented as a multifaceted, integrated development project. Within this framework the Ataturk Dam has been completed and water has been brought to the Harran Plain [5,7,15,17].

The region comprises eight provinces (Adiyaman, Batman, Diyarbakir, Gaziantep, Mardin, Sirnak, Siirt, Sanlıurfa) in Southeastern Turkey, bordering Iraq and Syria, and covers 73 863 km^2 of land which corresponds to about 10% of the total area of Turkey (Figs. 1 and 2). All of the six provinces in the GAP region are net out-migrating areas with the exception of Gaziantep. In spite of the above mentioned fact still the average annual growth of the Region's population has been 3.0% in the last 20 years, much higher than the national average of 2.5% [10]. Total population in the GAP region at the 2008 census was about 7.7 million which accounts for 10.5% of the national total of 73 million. The GAP region is one of the less developed regions in Turkey, and its per capita gross regional product was 47% of the per capita gross domestic product of Turkey in 1985 [7,9,15,17].

The GAP project originally planned by the State Hydraulic Works is a combination of 12 major projects primarily for irrigation and hydroelectric generation. The project includes the construction of 22 dams and 19 hydroelectric power plants on the Euphrates and the Tigris rivers and their tributaries. It is planned that upon completion, over 1.8 million hectare of land will be irrigated and 27 billion kWh hydroelectric energy will be generated annually [19]. On the other hand, it is assumed that in addition to energy production and improvement in agricultural sectors, the effects of this project on the social structure of the region will be considerable. The main objectives of the GAP project are to increase the economic conditions and well-being of the people of the area as well as the utilization of the potential resources. The project seeks an integrated purpose for development [7,8].

6. Energy situation of Turkey

Turkey's energy demand is met through thermal power plant consuming coal, gas, fuel oil and geothermal energy, wind energy and hydropower. Because Turkey does not own any nuclear power plant yet, the installation of first nuclear power plant with a capacity of 1000 MW is on the schedule as a plan of the near future. In 2008, the energy consumption of Turkey is about 106 525 kilo tons of oil equivalent (ktoe) as shown in Table 1 and Fig. 3. Turkey's installed generation capacity is also 41 818 GW and electricity generation is 198 418 GWh in 2008. According to Turkey's Ninth Plant, 66% of Turkey's generated electricity is supplied from thermal power plants [4]. Contribution of wind and hydro power plants are 0.2% and 32.20%, respectively [20–25]. 49.00% of Turkey's electricity is generated by Electricity Generation Incorporation (EUAS), 39.70% is generated by auto-producers, and 9.5% is generated by affiliated partnerships of EUAS and 1.8% by distribution of electricity generation by primary resources.

According to Ministry of Energy and natural Resources (MENR), Turkey has 259 billion kWh hydroelectric energy potential, but only 35% of this potential can be used [20]. Nowadays, Turkey's

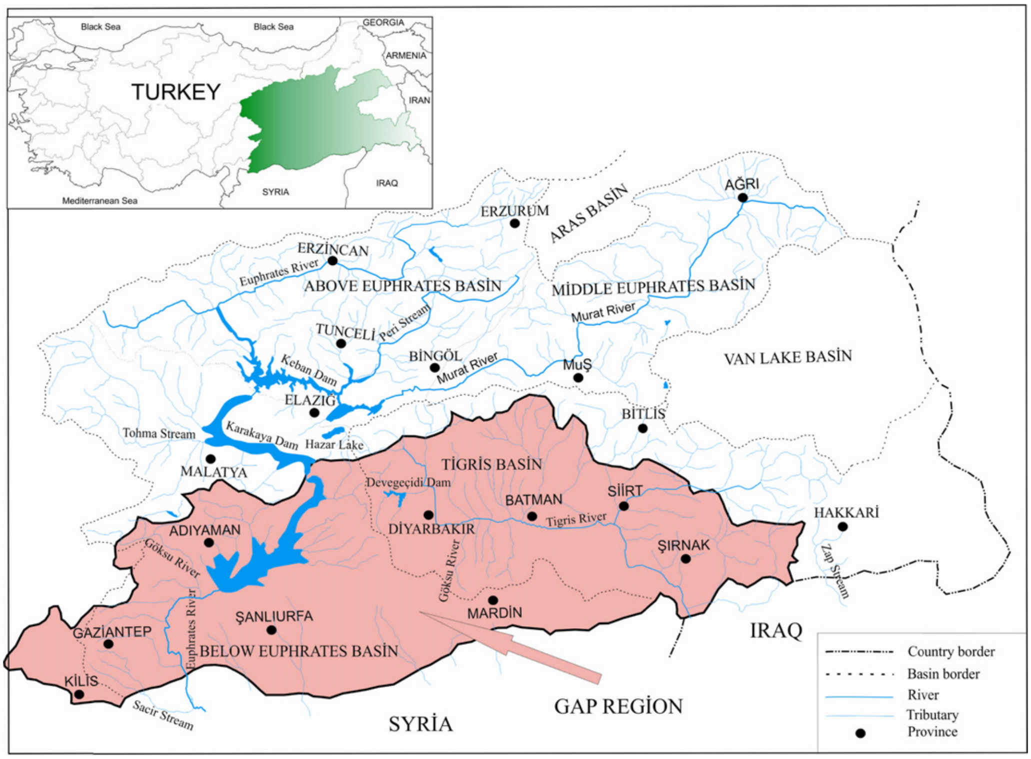

Fig. 1. Location map of Euphrates and Tigris Basins and GAP region.

electricity generation is approximately 176 billion kWh per year and will be 400–500 billion kWh per year by year 2020. As it is seen in Fig. 4, the electric energy generation sources are thermal and hydro power plants. At the end of 2009, comparing thermal power plant installed capacity to hydro; thermal capacity is big more than twice and 49% of the thermal source is derived from natural gas [22]. Turkey does not have enough primary energy sources, but has a tremendous hydropower potential [24]. Nowadays, hydropower is recognized as the most important kind of renewable and sustainable energy sources. The position of hydropower plants becomes more and more important in today's global renewable technologies. The small-scale renewable and distributed generation may be

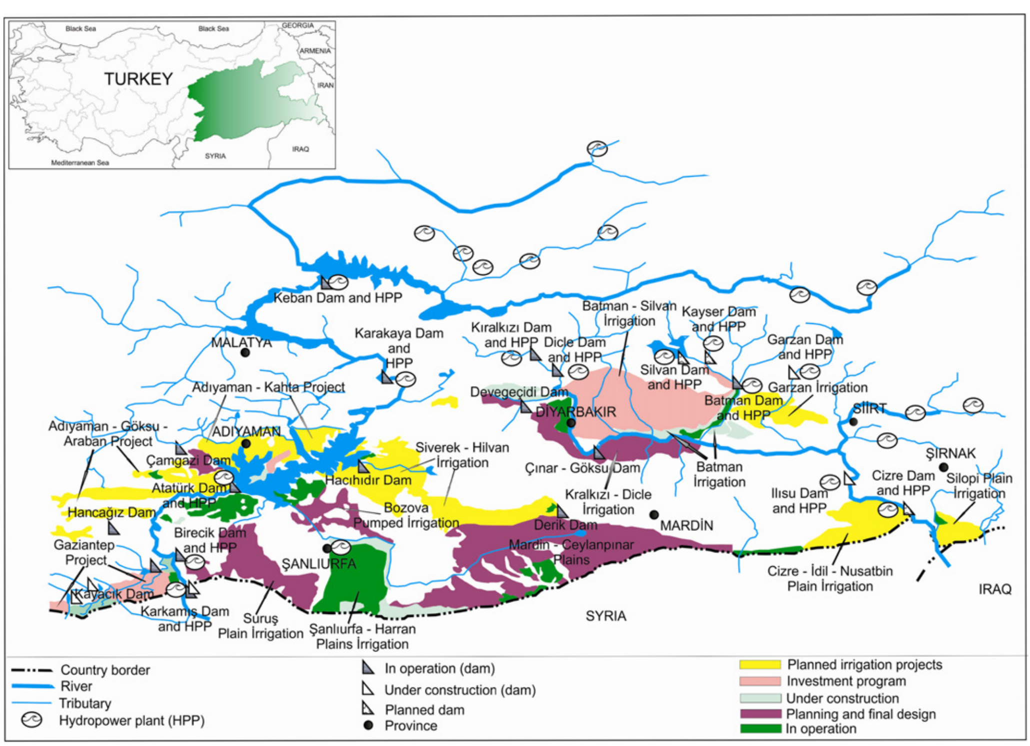

Fig. 2. Southeastern Anatolia Projects (GAP Projects).

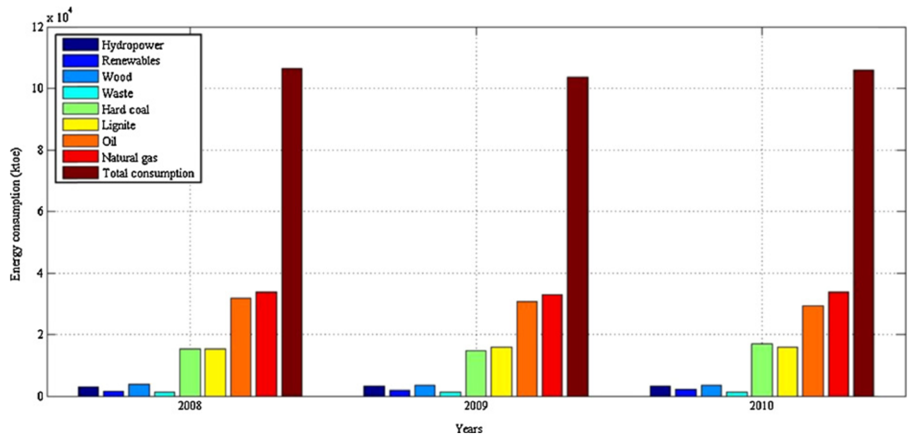

Fig. 3. Primary energy consumption by energy sources in Turkey [5].

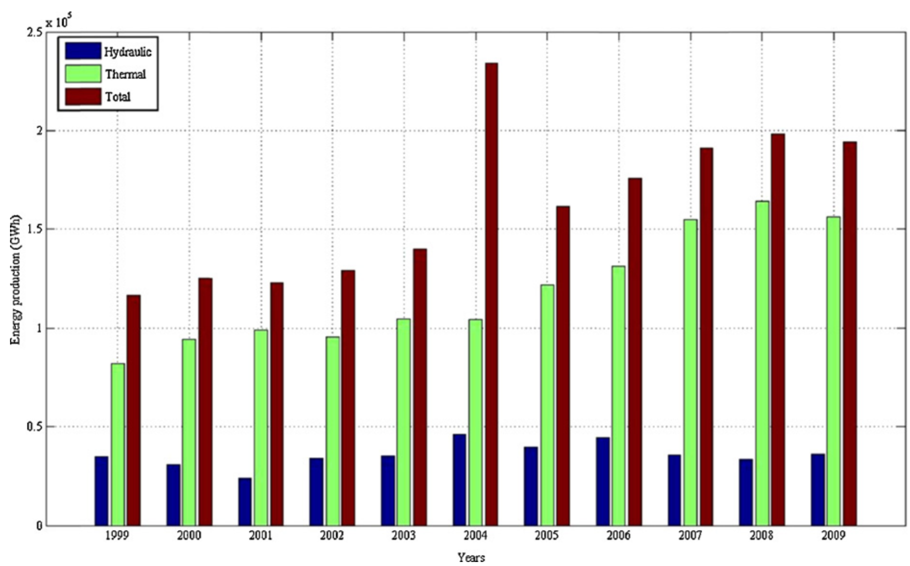

Fig. 4. Electric energy production comparison between hydraulic and thermal sources for Turkey [20,21].

the most cost-effective way to bring electricity to remote villages that are not near transmission lines [26–30].

In terms of hydropower potential, with 440 TWh/year, Turkey is the second richest country after Norway in Europe. This potential can be used technically 215 TWh/year and economical potential 128 TWh/year in accordance with the predictions of General Directorate State Hydraulic Works (DSI). 35% of the economically feasible hydropower, total 45.155 GWh/year is in operation, 8% (10.129 GWh/year) is under construction and 57% (72.339 GWh/year) is being designed [25–27].

Table 1
Primary energy consumption in Turkey (ktoe) [20].

Energy sources	2008	2009	2010*
Hard coal	16 427	14 768	16 861
Lignite	15 217	15 672	15 891
Petroleum products	31 784	30 652	29 312
Natural gas	33 807	32 774	33 603
Hydroelectricity	2861	3091	3354
Renewable energy	1645	1910	2102
Wood	3679	3530	3591
Animal waste and plant residue	1134	1150	1120
Total primary energy consumption	106 555	103 547	105 834

ktoe, kilo tons of oil equivalent.
* Estimate.

Water and hydropower potential in Turkey are distributed into 26 basins and the total flow rate of water sources for energy production is 186 km^3/years. The biggest five basins of Turkey are Euphrates, Tigris, Eastern Black Sea, Coruh and Seyhan. Euphrates represents over 38% of the national hydropower potential, Tigris represents over 16% of the national potential, Eastern Black Sea represents 11% of the national water supply, Coruh represents 10.5% and Seyhan represents 7.3% of the national water and hydropower potential. Table 2 shows the economically feasible hydropower in Turkey [16,19,26–30].

The construction of more than 329 hydropower plants is projected to add a total installed capacity of 19 699 MW, thus the total number of hydro plants is to bring to 483 and will be the total installed capacity of 34 592 MW by 2020 [20]. This increase includes the Southeastern Anatolia Project (GAP) which covers one-tenth of Turkey's total land area. GAP will have an installed capacity of 7460 MW [7,10]. Following the succession of this project, 1.7 million hectares of land will be irrigated and the ratio of irrigated land to the total GAP area will increase from 2.9% to 22.8% while that for rain-fed agriculture will decrease from 34.3% to 7% [7,10,19]. On the other hand, 27 billion kWh of electricity will be generated annually over an established capacity of 7460 MW. The

Table 2
The status of economically feasible hydropower potential in Turkey [16].

Project	Number of project	Total installed capacity (MW)	Annual average energy (TWh/yr)	Ratio (%)
In operation	172	13 700	48	35
Under construction	148	8600	20	14
In program	1418	22 700	72	51
Total	1738	45 000	140	100

area to be irrigated accounts for 19% of all the economically irrigable area in Turkey (8.5 million hectares), and the annual electricity generated will account for 22% of the country's economically viable hydroelectric power potential, 118 billion kW. By 2006, the Ataturk and Karakaya Dams, the most important investments of the GAP, had generated almost 145 billion kWh energy [7].

Turkey total hydropower capacity is estimated at 440 TWh per year. Some of this potential can be achieved with small hydroelectric plants (SHPs) having individual capacities of 10 MW or less. It is estimated that, theoretically, Turkey has SHP resources of 710 GW for project generation and 300 MW for total installed capacity [18,25]. SHP development in Turkey was initiated in 1900. Since then, municipalities in rural areas have installed many decentralized plants by private entrepreneurs, and by some government organizations. It is estimated that, Turkey has SHEP resources of 710 GW for project generation and 300 MW for total installed capacity [11,12].

7. Dams and sustainable development

When the literature is analyzed, it can be said that from 1930s, comprehensive projects including the construction of great dams to increase the efficiency of agriculture and to provide water and energy, has been created as a part of the regional development efforts. But after 1975, when the sensitivity towards the harmful effects of great dams to environment raised, the construction numbers are decreased. Despite this fact, during the 20th century, on the entire world approximately 48 000 dams were built, and today there are great dams on nearly half of the rivers of the world. Six percent of the energy consumed in the world is produced from hydraulic power. Additionally, hydraulic power is in the second rank within the renewable energy sources and every year it increases 4% in the world [2,5,16].

The construction reasons of dams may vary within countries or even within regions of a country, according to the climate and scare resources. In some counties, to prevent floods, in some because of possible danger of drought, in some to increase the efficiency of agriculture by manual watering of plants, and some others to provide electricity or to meet all these needs the dams are built. But it is generally accepted that first dams of the world are built to render agricultural production continuously [5,16].

Because of that the environmental and social effects of small dams are much more limited than the bigger ones, some contemporary perspectives interpret small dams as ‘success’ and bigger ones ‘problem’. According to this perspective, the people who take the most benefit from the bigger dams is rich ones, in other words they generally service to richer people. On the contrary, poor people's chance of getting benefit from small dams is much bigger. Also it is proposed that small dams serve for the protection of traditional production styles. In spite of many benefits of dams, at the end of 1970s and the beginning of 1980s, when the sustainable development started to be discussed in the public and the care for environment raised, generally the negative effects of dams are pointed out during discussions. These negative effects can be grouped as “effects on environment” and “effects on people” such as [2,5].

7.1. Environmental effects

The quality and wideness of environmental effects of dams are subject to change according to the purpose of dams. In other words, the effect area of a dam is subject to change according to the their purpose; which can be ‘flood control’, ‘irrigation’, ‘drinking water’, ‘electricity production’, or all of them. One of the most significant environmental effects of dams is the climate change they cause. Whatever the reason for the construction of dam, the water in the reservoir area increases the humidity ratio and softens the climate. This change may also effect the flora. Even a farmer from Şanlıurfa said that, “after the construction of the dam, because the peanuts got rot on the trees, he has removed all the trees” and added that “it is impossible to be a peanut farmer in Şanlıurfa anymore”. That observations were also affirmed by the experts of the Agricultural Directorates of Şanlıurfa, during the interviews. Again in a study in Adana, which explores the effects of the Dam of Aslantaş, it is stated that the fig trees became unfruitful because of the raised humidity [5].

Apart from their effects on the flora, it is also stated that great dams have effects on the fauna of the region; and it is founded that while increasing the quantity of some animal species they also decrease the quantity of some other species. The raised humidity caused by the dam and irritation creates a suitable environment for species like mosquito and white flies. That raise in the number for the quantities of referred species increases some diseases in the local communities, such as malaria and eastern blain and other dermal problems. Another effects of dams that should be seen as a part of their effects on environment are on the archeological treasures and historical areas.

Lastly, another indirect consequence of the dams over environment is about agriculture-with-water. But irrigation is different, its subject is humans. Because the ones who prepare plans for irrigation projects do not know the territorial qualities of the area, the possible ways that the farmers on that area would use the water and the lack of drainage channels that would remove the extra-water, the water levels raise, the area becomes ineffective, the agricultural production lowers and in the final analysis, the land becomes arid and waste. According to the estimations, 50–80% of the area on the world is under the danger of being waste because of the wrong methods of irrigation and every year an area of 60 million hectares turns into “salt lakes” in the world [2].

7.2. Social effects

In Turkey, as well as in the world, the most significant social effect of the dams is the re-settling of local communities, whose residential areas are invaded by the dams reservoir area. This necessitates the families to built new daily routines in a new locality. So, re-settling consists of two related but somehow separate processes. Producing electricity or building irrigation systems requires many people to be unvoluntarily dislocated. For example a big hydroelectricity complex in Canada, or great dams in China and India necessitate many local communities to be separated from their roots [2,5,9].

According to the "Dams and Development" report of the World Commission on Dams [2], the increasing relocation in the developing countries because of dams and other reasons, causes a number of problems because of the scare resources of these countries. Although there are important developments about relocation, the problems and difficulties are still available and generally the results are lower than expected. The cost of unsuitable settlements becomes high and results in the raising of poverty for many people. These people are forced to live areas that have insufficient infrastructure and social services. The local communities and ethnic groups are settled very far of the dam area.

As expected, it is possible to give many examples either from Turkey or any other country, about the people dislocated because of great dam projects. Though some differentiation can be observed between different countries' experiences according to local conditions or relocation policies, some important commonalities are pointed out in the studies carried out on the people subjected to re-settlement [5,7,9]:

- the unvoluntariness to re-settlement,
- decrease in the income/dispersal in the classical production systems,
- dispersal in community structure,
- decrease in authority and inter-assistance potential,
- change in cultural identity.

It is important to note that, it would be inaccurate to oppose resettlement policies by referring to above mentioned explanation which partially includes the problems of these policies. Especially developing countries may be in need of hydroelectric power and big irrigation projects, and great dams are many times seen as an answer to these needs. So, resettlement may be seen as inescapable during the process of development. The main problem at this point is to find out the ways by which, resettlement can be planned best, the problems caused by it decreased to minimum and the meets of the people who are dislocated met at a maximum level. To achieve these aims, all the problems that are caused by the project with the possible solutions of them should be clarified in the planning phase of the project, with the participation of the local communities that will be effected [5].

Because of the effects referred above, the discussions on the dams functionality are raised, and many people opposed the construction of any more great dams, in the 21st century. The main point of these discussions is one question: "Are great dams sustainable?" That's the crucial question because, despite the invested million dollars to dam projects, cost of these dams has been even bigger [5]. Especially the costs that repaid because of the environmental effects of dams and the need to resettle the local communities, put the sustainability issue of these into question and forced people to find what to be done to make them sustainable. For example on the report of World Commission on Dams, which is prepared by examining nine countries including Turkey, all the dams projects are proposed to be reexamined and conscious participation of local communities to dam projects is offered, to ensure the sustainability of these projects [2].

However, in big-scale projects, including the construction of great dams, a different kind of participation is anticipated. For example, a great importance is attached to the public meetings and discussions about the aimed project's benefits for development and effects to environment; at which people can share their point of view and reach the information through the technical-social experts' speeches. Furthermore, when the social and environmental effects of a planned project are above a certain level, the examination of the project by the public is referred as a must and in some cases, referendum is offered as an important tool to decide if to realize such projects [2].

Table 3
Energy production in GAP [7,19].

Name of dam	Yearly energy production
Karakaya Dam and HPP	106.8 billion kWh
Ataturk Dam and HPP	74.5 billion kWh
Kralkızı Dam and HPP	0.3 billion kWh
Karkamış Dam and HPP	0.6 billion kWh
Dicle dam and HPP	0.1 billion kWh
Birecik Dam and HPP	1.6 billion kWh
Total	183.9 billion kWh

The sustainability of the dam projects also depends on to reach the optimum balance between winners and losers. At this point, justice and the balanced distribution of resources are important. Technical and socio-economical opportunities that will make people productive equal opportunities in the fields of education, health and business. For example with the construction of them, two main groups appear. The ones who can evolve through irrigated agriculture, and the ones who should be dislocated. For the second group of people, new ways to earn their life should be created and at least, it should be endeavored to protect their previous life quality [2,8,16].

8. Energy production in the GAP

Together with the Atatürk and Karakaya dams which combined provide a significant share of energy in the interconnected system, the total energy production by the hydropower plants of the region, including Kralkizi, Karkamış, Dicle and Birecik which started operating in 1999 and 2000, reached about 184 billion kWh yearly electricity production (Table 3). On the other hand, the monetary equivalent of 186 billion kWh energy generated in the period between the first operation of plants and the end of 2009 is about US$ 14 billion. If this magnitude is expressed in terms of alternative energy sources, it is comparable to the importation of 50 million tons of fuel oil. Turkey produced about 36 billion kWh hydraulic energy in 2009. In this total, the GAP region has a share of 34% as shown in Table 4 and Fig. 5.

8.1. Atatürk Dam

Ataturk Dam and hydroelectric power plant (HEPP) which is in the Lower Euphrates projects, is the most important and key structure of both this project and Southeastern Anatolian Project. It is located at 24 km to Bozova town of Sanliurfa. Ataturk Dam has been listed in international construction publications as the world's largest construction site. It was planned and implemented by the State Hydraulic Works (DSI) and the construction began in 1983 and completed in 1992 [7,14,19].

The rock formations at the construction site show mainly a cretaceous and tertiary age. The oldest rock formation is the dolomitic limestone of Upper Cretaceous. The lower part of the rock sequence is intercalated by cherty layers while the upper levels locally contain marly and even chalky layers. The spillway structure has an ogee type with six bays, each one controlled by a 16.0 m × 17.0 m radial gate. Its maximum discharge capacity is of 16 800 m^3/s with the water level in the reservoir at elevation 544 m. Three diversion tunnels lie on the left bank with parallel longitudinal centerlines spaced at 30.0 m each. The typical cross-section is horseshoe shaped with an inside diameter of 8.0 m. The maximum discharge capacity of each tunnel is 850 m^3/s. Total irrigation area of the Ataturk Dam is 872 385 ha.

Ataturk Hydroelectric Power Plant is equipped with 8 units, each of units has 300 MW installed capacity. It began generating power in 1992 and has produced almost 93.4 billion kWh until now. Upon the completion of irrigation projects supplying water from Ataturk Dam, there will be naturally significant changes in

Table 4
Energy production comparison between GAP and Turkey [20,21].

Year	Turkey			GAP Hydraulic GWh	GAP/Turkey	
	Thermal GWh	Hydraulic GWh	Total GWh		Hydraulic (%)	Total (%)
1999	81 804	34 668	116 432	14 864	42.7	12.7
2000	94 187	30 899	125 026	12 160	39.2	9.7
2001	99 064	24 024	123 021	11 509	47.9	9.3
2002	95 464	33 712	129 016	12 420	36.8	9.6
2003	104 810	35 346	140 115	15 298	43.3	10.9
2004	104 214	46 112	234 010	22 410	48.7	14.8
2005	121 912	39 643	161 524	18 708	47.2	11.6
2006	131 405	44 244	176 079	21 414	48.5	12.2
2007	155 021	35 836	191 168	18 224	51.0	9.5
2008	164 298	33 324	198 392	15 642	47.0	7.8
2009	156 214	35 914	194 060	12 121	33.7	6.2

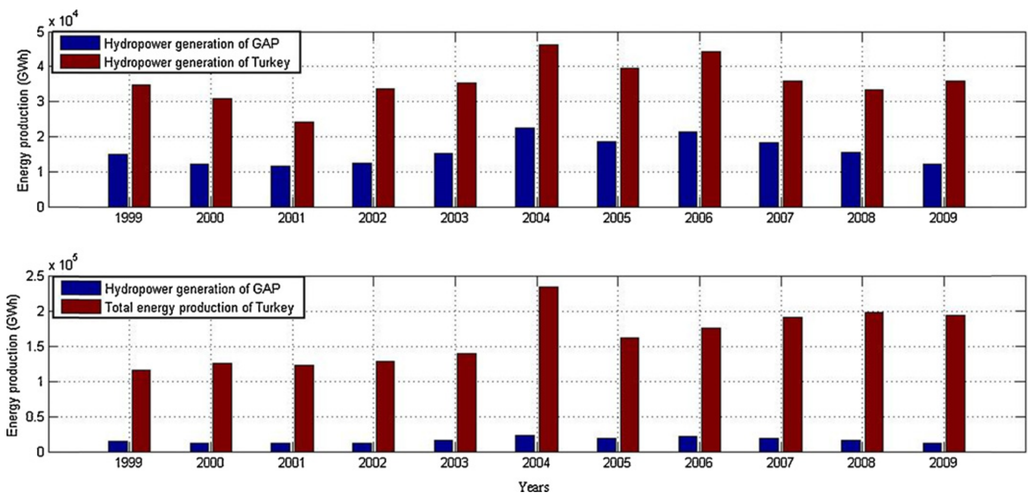

Fig. 5. Energy production comparison between GAP and Turkey [20,21].

agricultural output and crop design in the region and consequently in the life standards of people living there. Such irrigation-led crops like vegetables, soybean, groundnut, sunflower, cotton, corn, lentil and chickpea, almond, pistachio and fodder crops will be the basis of flourishing agro-industries. In the Organized Industrial Districts of Sanliurfa, Adiyaman and Gaziantep will be established processing and packaging plants for agricultural production. Specifications and overview of Ataturk Dam and HEPP are shown in Table 5 and Fig. 6, respectively [7,16].

Dam reservoirs are artificial lakes where fish-life should be able to develop as in natural lakes and provide an abundant source of food for lakeside populations as well as opportunities for recreational fishing. Ataturk Dam Lake like some other reservoirs has even become well known in this respect. By commercially fishing in the reservoir it has been gained 1.26 million USD per year with a catch of approx. 1000 tons of some fish species. In addition to commercial fishing it has a potential of 7000 tons/year cage culture and may offer a market value of 14 million USD [7].

Sanliurfa-Harran irrigation scheme began operation in 1995. Irrigation water has been supplied from Atatürk Dam. Gross irrigation area of the project was 31 285 hectares in 1995. Irrigation area has been increased in the following years and reached to 121 138 hectares in 2003. When the construction of whole irrigation facilities of the project will be completed, the irrigation area

Fig. 6. Overview of Atatürk dam (left side) and Keban Dam (right side).

Table 5
Specifications of Atatürk and Keban dam and hydroelectric power plants.

Item	Atatürk	Keban
Power plant		
Start of operation	July 1992	October 1975
Average annual generation	8900 GWh	6000 GWh
Maximum output	2400 MW	1330 MW
Maximum power discharge	241 m^3/s	136 m^3/s
Maximum effective head	152 m	145 m
Dam		
Type	Centralized clay rockfill	Centralized clay rockfill + concrete
Crest length	1670 m	1126 m
Maximum height	170 m	211 m
Volume	84 500 000 m^3	15 585 000 m^3
Design flood discharge	16 800 m^3/s	17 000 m^3/s
Reservoir		
Catchment area	92 240 km^2	64 100 km^2
Impounding area	817 km^2	675 km^2
Maximum capacity	48.7 billion m^3	30.6 billion m^3
Maximum water level	544	845
Minimum water level	526	800

would be 872 385 hectares. Main crops in irrigated area are cotton and grains. Irrigation ratio was 82% in DSI developed irrigation areas in this project including second crop areas and irrigated areas outside of the command area. Yield increase in a unit area provided by irrigation is a unique element for increasing agricultural production value and added value. Yield increases in Sanliurfa-Harran irrigation scheme compared to without project situation are as follows: 111% grains, 54% legumes, and 69% cotton.

The GAP region was in a disadvantaged position compared with other regions in the country from a socioeconomic point of view and its relative economic importance had decreased continuously over the last half century. The inter-regional disparities and rural-urban differences were hindrances to development. The GAP project aims to reverse this situation by using geographical and local advantages of the region to alter the natural course of socioeconomic change and expedite development efforts. Atatürk Dam will provide irrigation water to an area of 900 000 hectares, which is larger than the half of the area to be irrigated within GAP Project. At present, although only 200 000 hectares are being irrigated from Atatürk Dam, it can be said that irrigation has brought the spread of commercial crops and modernization of agricultural production in the region. On the other hand hydroelectric power production of Ataturk Dam has become about 93.4 billion kWh since 1992, which is a quite important figure in the electric production of Turkey. Atatürk Dam also provides drinking water for the city of Sanliurfa and some other smaller cities [7,19].

8.2. Keban Dam

Upon the decision to utilize water resources in a rational manner and to meet the needs for electricity in particular appeared on the forefront as one of the most urgent issues, the Electricity Survey Administration (EIE) was established in 1936 to produce energy from otherwise vainly flowing streams of the country. The Administration started its preliminary surveys intensively with the "Keban Project". In order to carry out studies on the river Euphrates with respect to various characteristics, the Administration established gauging stations on various points along the river [7].

Geological and topographical works over the narrow passage of Keban started in 1938. Then, in the period 1950–1960, emphasis was shifted by the EIE on drillings on the Euphrates and the Tigris. Later, upon the emergence of new needs, another organization, the State Hydraulic Works (DSI) was established in 1954 and took over the responsibility of development of Keban Dam and HEPP. Its construction started in 1965 and was put in operation in 1975 by DSI. On the other hand, the Keban Dam and HEPP is located at 45 km north west of Elazıg, 65 km north east of Malatya, 10 km from the confluence of Karasu and Murat tributaries and at 3 km upstream of Keban town, Elazıg province. The water enters the Keban Dam reservoir through the tributaries Karasu and Murat from catchment area of 64 100 km^2 with 150 km wide and 425 km long [7,14,19].

The dam is founded on metamorphosed rocks of Paleozoic Period, which had been exposed to a lot of tectonic incidence. At the top white and pink colored, karstic and karstified calcareous and marble and below calcareous schist and dolomitic black lime stone layers are present. This formation was deformed by a lot of faults and breaking systems. One of these faults caused the fall of the ground in about 110 m and formed a narrow deep valley there. For this reason evaporation lose from water surface area of Keban Dam is considerably less than that of dams which has large water surface area.

The dam is a mixed structure formed of two different dam types, rock fill dam and concrete gravity dam. The rockfill section forms the main dam. The length of this section is 601.00 m from the right bank rock surface to the north gravity blocks. The concrete part including intake and spillway is 524.00 m long. Total crest length is 1125.00 m. The rockfill part is composed of clay-cored and compacted rock of 211 m high from the foundation. On the other hand, diversion tunnels, intake structure and spillway are arranged on the left side of the valley. The power intake, spillway and gravity blocks were designed to complete the integrity of the structure and to conform to the topography. The spillway has 6 radial gates for a discharge capacity of 17 000 m^3/s in total. Water discharged through the spillway is channeled to the downstream through a 124 m wide and 400 m long chute and a flip bucket at the end of this chute.

The power plant has a capacity of 1330 MW, equipped with 8 units, first four of each 157.5 MW and other four units installed later on of each 175 MW capacity. It began generating power in 1975 and has produced almost 176.4 billion kWh until now. Specifications of Keban Dam and HEPP are shown in Table 5 and Fig. 6 [7,16].

The necessity of electric energy was 18 153 GWh between the year 1956 and 1962 in Turkey. It was increasing 13% every year and the requirement of it would be 82 025 GWh in the period of 1963–1973. For this reason the Keban Dam and HEPP is a very important project to produce electricity for Turkey. Total produced energy since 1975 is 176 400 GWh, with average energy production of 6000 GWh per year. After the operation of Keban dam, additional energy production is 6000 GWh per year. In parallel with construction of the Keban Dam and HEPP, 380 km transmission lines were constructed to connect Keban, Ankara and Istanbul, and electricity generated contributed to improvement of economy of not only the region but also the country as a whole.

The second drought season started in 1970 and ended in 1975. The most drought year in the stated period was 1975. The annual discharge decreased to 18.8 billion m^3. This amount corresponded with the 59% of average annual discharge in the long run. In two drought periods, due to the Keban Dam under construction, the negative effects of drought years decreased not only in Turkey but also in Syria and Iraq. As an example, in 1989 if the Keban Dam had not been constructed, 20.8 billion m^3 water annually would have been released across the border. This amount reached to 25.7 billion m^3 by increasing 4.7 billion m^3 due to regulation effect of the dam.

As indicated above, the Keban HEPP has produced 6000 GWh/year and this means that it has recovered its construction cost 7 times so far. As well as its energy production the project has also a potential irrigable area of 55 755 ha, and approximately 1000 tons of fish production per year. Before the operation of the dam, negative effects of two drought seasons

Table 6
Water and land resources development projects in the GAP region [7,19,20].

Project	Capacity (MW)	Production (GW)	Irrigation area (ha)	Present stage
Karakaya Dam & HEPP	1800	7354		OP
Lower Euphrates Project				
Atatürk Dam & HEPP	2400	8900		OP
Şanlıurfa HEPP	50	124		OP
Şanlıurfa Irrigation Tunnels			476 000	OP
Siverek-Hilvan Pumped Irrigation			160 000	E
Bozova Pumped Irrigation			70 000	E
Border Euphrates Project				
Birecik Dam & HEPP	852	3168		UC
Karkamıs Dam & HEPP	180	652		DD
Suruç-Baziki Plain Irrigation			146 500	E
Adıyaman-Kahta Project				
Adıyaman-Göksu Dam & Irrigation	7	43	71 600	FS
Çamgazi Dam & Irrigation			7430	UC
Koçalı Dam & HEPP	40	120	21 605	MP
Büyükçay Dam, HEPP & Irrigation	30	84	12 322	MP
Kahta Dam & HEPP	75	171		MP
Pumped Irrigation from Atatürk Dam			29 599	MP
Gaziantep Project				
Hancağız Dam & Irrigation			7330	OP
Kayacık Dam & Irrigation			14 740	UC
Pumped Irrigation from Birecik Dam			66 000	FS
Dicle-Kralkızı Project				
Kralkızı Dam & HEPP	94	146		UC
Dicle Dam & HEPP	110	298		OP
Dicle Right Bank Gravity Irrigation			54 280	UC
Dicle Right Bank Pumped Irrigation			75 870	UC
Batman Project				
Batman Dam & HEPP	198	483		OP
Batman Left Bank Gravity Irrigation			9570	UC
Batman Left Bank Pumped Irrigation			9180	FS
Batman Right Bank Gravity Irrigation			18 600	DD
Batman-Silvan Project				
Silvan Dam & HEPP	150	623		E
Kayser Dam & HEPP	90	341		E
Dicle Left Bank Gravity Irrigation			250 000	E
Garzan Project				
Garzan Dam & HEPP	90	315		E
Garzan Irrigation			60 000	E
Ilisu Dam & HEPP	1200	3830		DD
Cizre Project				
Cizre Dam & HEPP	240	1208		DD
Nusaybin Cizre Irrigation			89 000	E

OP, in operation; UC, under construction; E, Exploration; DD, detailed design completed; FS, feasibility study; MP, master plan.

in the upper basin were felt by the two riparian countries, Syria and Iraq. After construction, the dam has a function of regulating the Euphrates River. Since Keban dam is on the upstream part of Euphrates River, it also protects the other dams downstream which are under operation and construction in terms of flood. Additionally, workers and technical employees gained talent and found job during the construction of dam [7,9,17].

9. Water potential of the GAP

The GAP area is rich in water resources. The Euphrates and Tigris rivers represent over 28% of the country's water supply by rivers, and the economically irrigable areas in the region make up 20% of those for the whole Turkey. The development of the region was originally planned as relating to its water resources, which were later combined in a comprehensive water and land resources development package. For this purpose, total 12 groups of projects were planned on the Euphrates and Tigris rivers and their branches by the General Directorate of State Hydraulic Works (DSI) as shown in Table 6 [7,19].

The package included the construction of 22 dams, 19 hydroelectric power plants and the irrigation facilities to serve 1.7 million hectare of land. The total installed capacity of the power plants is 7500 MW with an annual production of over 27 billion kWh. There are two main basin projects: the Euphrates and Tigris basin projects. The Euphrates basin projects have 5304 MW installed capacity, will generate 20 billion kWh of energy and will irrigate 1.0 million hectare of land. Fourteen dams and 11 hydroelectric power plants are planned for this basin. The Tigris basin projects have 2172 MW installed capacity, will generate 7 billion kWh of electric energy and will irrigate 700 000 ha of land area. Eight dams and eight hydroelectric power plants are planned for this basin [7,19].

The Lower Euphrates Project is one of the GAP schemes on the Euphrates river and consists of Ataturk Dam and Hydroelectric power plant (HEPP), Sanlıurfa tunnels and hydroelectric power plant, Sanlıurfa-Harran irrigation, Mardin-Ceylanpınar irrigation, Siverek-Hilvan pumped irrigation. Main public investments in this project have been completed. Atatürk dam was completed in 1990 which the sixth largest volume dam (48.7 billion m^3) in the world. Type of dam is rock packed with 169 m high from river bed and 1664 m crest long. Body packed volume of the dam is 84.5 million m^3. Water reaches from the Ataturk dam to Sanlıurfa-Harran plains via the Sanlıurfa tunnels system, which consists of two parallel tunnels each 26.4 km long and 7.62 m in diameter. This irrigation tunnel system is the largest of its kind and it has numerous irrigation networks, canal systems constitute the physical groundwork in water resources. Tunnels were completed in 1997, and irrigation is now practiced in a 250 000 hectares (total is 476 000 ha) [7,19].

10. Conclusions

Water power has been utilized since the dawn of history, but only its transformation into electrical energy established the basis for its expansion today to around 44% of the country potential. And hydroelectricity will be continued in the future to be one of the most effective options because of the zero emission involved and domestic energy source. On the other hand, water is one of the most valuable resources, and a limiting factor for crop production. Agricultural crops are the major consumer of water. Agriculture, with its social and economic aspects, has a dominant role in the nation's life in Turkey. It accounts for about 20% of gross domestic product, 10% of exports and 47% of civilian employment.

The GAP project is one of the largest power generating, irrigation, and development projects of its kind in the world, covering 3 million ha of agricultural land. This is over 10% of the cultivable land in Turkey; the land to be irrigated is more than half of the presently irrigated area in Turkey. The GAP project on the Euphrates and Tigris Rivers encompasses 20 dams and 17 hydroelectric power plants. When all projects are completed, 27 billion kWh of electricity will be generated annually, which is 45% of the total economically exploitable hydroelectric potential. As a multipurpose regional development project, the implementation of the GAP will be carried out as scheduled. The environmental impact assessment studies for the GAP will be put into effect. Similar studies for other regions will be carried out when required. In the GAP region, development work will be completed before the irrigation projects. Meanwhile the farmers of the region will be imparted extension services, especially training and land consolidation, with irrigation activities, will be handled on a faster pace.

References

[1] Gleick PH. The changing water paradigm: a look at twenty-first century water resources. Development Water International 2000;25:127–38.
[2] WCD, World Commission on Dams. Dams and development: a new framework for decision-making. London: Earthscan; 2000.
[3] Kaygusuz K. Sustainable development of hydropower and biomass energy in Turkey. Energy Conversion and Management 2002;43:1099–120.
[4] DPT, State Planning Organization. Ninth Development Plan (2007–2013). Ankara, Turkey: Prime Ministry of Turkey; 2010.
[5] Parlak ZG. Dams and sustainable development. Istanbul, Turkey: International Congress on River Basin Management, General Directorate of State Hydraulic Works; 2006.
[6] Kaygusuz K. Renewable and sustainable energy use in Turkey: a review. Renewable and Sustainable Energy Reviews 2002;6:339–66.
[7] GAP, Southeastern Anatolia Project. Energy and water in the GAP region; 2009. http://www.gap.gov.tr/ (accessed 6.4.10).
[8] Kaygusuz K. Energy and water potential of the Southeastern Anatolia Project (GAP). Energy Sources 1999;21:913–22.
[9] Polatoglu A. Southeastern Anatolia Project and administrative organization. METU Studies in Development 1995;22:191–206.
[10] Kaygusuz K. Contribution of the Southeastern Anatolia Project (GAP) to irrigation and hydroelectric power production in Turkey. Energy Sources, Part B 2010;5:199–209.
[11] Yüksel I. Hydropower for sustainable water and energy development. Renewable and Sustainable Energy Reviews 2010;14:462–9.
[12] Yüksel I. Energy production and sustainable energy policies in Turkey. Renewable Energy 2010;35:1469–76.
[13] International Energy Agency. Energy policies of IEA countries: Turkey 2009 review. Paris: IEA; 2010.
[14] DSI, State Hydraulic Works. Turkey water report. Ankara, Turkey: DSI; 2009.
[15] Bagis I. Turkey's hydro politics of the Euphrates–Tigris Basin. Water Resources Development 1997;13:567–81.
[16] Altınbilek D. The role of dams in development. Water Science and Technology 2002;45:169–80.
[17] Altınbilek D. Development and management of the Euphrates–Tigris basin. International Journal of Water Resource Development 2004;20:15–33.
[18] Yüksek O, Kaygusuz K. Small hydropower plants as a new and renewable energy source. Energy Sources, Part B 2006;1:279–90.
[19] DSI, State Hydraulic Works. Hydroelectric power in Turkey; 2010. Available at: http://www.dsi.gov.tr/ (accessed 3.4.10).
[20] MENR, Ministry of Energy and Natural Resources. Energy report in Turkey; 2009. Available at: www.enerji.gov.tr/ (accessed 2.3.10).
[21] TEIAS, Turkish Electricity Transmission Company. Percentages of electricity generation by primary energy resources by 2009. Ankara, Turkey: TEIAS; 2010.
[22] WECTNC, World Energy Council Turkish National Committee. Turkey energy report in 2008. Ankara, Turkey: WECTNC; 2008.
[23] EIE. General Directorate of Electrical Power Resources Survey and Development Administration, renewable energy in Turkey, Ankara, Turkey, 2010.
[24] Ozturk M, Bezir NC, Ozek N. Hydropower – water and renewable energy in Turkey: sources and policy. Renewable and Sustainable Energy Reviews 2009;13:605–15.
[25] Alboyaci B, Dursun B. Electricity restructuring in Turkey and the share of wind energy production. Renewable Energy 2008;33:2499–505.
[26] Yüksek O. Reevaluation of Turkey's hydropower potential and electric energy demand. Energy Policy 2008;36:3374–82.
[27] Yüksek O, Kömürcü MI, Yüksel I, Kaygusuz K. The role of hydropower in meeting Turkey's electric energy demand. Energy Policy 2006;30:3093–103.
[28] Akpınar A, Kömürcü MI, Kankal M, Ozölçer IH, Kaygusuz K. Energy situation and renewables in Turkey and environmental effects of energy use. Renewable and Sustainable Energy Reviews 2008;12:2013–39.
[29] Akpınar A, Kömürcü MI, Kankal M. Development of hydropower energy in Turkey: the case of Coruh river basin. Renewable and Sustainable Energy Reviews 2011;15:2013–39.
[30] Kaygusuz K. Hydropower in Turkey: the sustainable energy future. Energy Sources, Part B 2009;4:34–47.